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AUTOMATIC MONITORING OF WATER QUALITY

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Eleven automatic water quality monitoring stations have been used, of which five are part of a computer controlled system in the rivers Kymijoki and Kokemäenjoki and the others are mobile stations. The parameters measured are temperature, pH, conductivity, dissolved oxygen and turbidity, and at five stations also chloride. The major causes of disturbances associated with water intake and malfunction of microprocessors and the central computer. Effective operation times varied between 30 and 100 % of the total measuring time. Automatic monitoring has in several cases revealed previously undetected variations in water quality. Of the 5–6 measurement parameters used, at least one always reacted to changes in water quality. The primary data obtained has been utilized with the aid of statistical methods in an attempt to determine the necessary sampling frequency for a given confidence of calculated means.

Index words: Automatic monitoring, water quality, effective operation time, sampling frequency.

1. INTRODUCTION

The Finnish National Board of Waters has been actively engaged in the development of automatic water quality monitoring since the early nineteen-seventies. In 1972 an automatic water monitoring system for experimental and research purposes was commenced in the course of the river Kokemäenjoki. The purposes of the system were immediate detection of the discharge of raw materials, products and wastes into the watercourse, with the ultimate aim of preventing such discharges, and the automation of an obligatory monitoring duty with the aid of continuous measurements (Tiainen et al. 1974, Vuolas 1976, Kohonen 1978a, b, c, 1979).

In 1974 and 1976 the National Board of Waters (NBW) obtained two mobile automatic water monitoring stations (AWMS). In the spring of 1977 a new system comprising five land based AWMS was completed at the river Kymijoki (Kohonen 1978a, b, c, d, 1979, Kohonen and Lee-Frampton 1979). The major advantages of this network in comparison with that in the river Kokemäenjoki were a data transmission system and a greater data processing capacity.

In 1980 the NBW obtained a mobile, Finnish-built AWMS, in which measurement takes place with the aid of a probe which is immersed into the water.

In this report the systems and measuring stations used by the NBW, and the results obtained, are described. Possibilities for utilization of the results are also examined.

2. SYSTEMS AND MONITORING STATIONS

2.1 The monitoring system of the river Kokemäenjoki

This system, delivered for use in research in February 1976, included in its original form three river stations and nine measurement sites at a wood processing factory. Of the latter, four were situated at the effluent drains and five were at different points within the factory in the waste water line leading to the treatment plant. Detailed descriptions of the equipment and the functioning of the system have been published by Tiainen et al. (1974), Vuolas (1976), Muhonen (1976), Kohonen (1976, 1978a, b, c, 1979), Kohonen et al. (1978) and the National Board of Waters (1978).

Because of fouling and clogging of the measuring devices the development work was interrupted for the rectification of faults in the construction of both the river stations and the factory sites. From the beginning of 1978 lack of funds necessitated the concentration of the development work to two of the river stations. The work of the project was hampered by the fact that the technical properties of the stations did not fulfil expectations in the polluted waters of Nokianvirta and of the effluents. Satisfactory measurement would have necessitated an excessive amount of servicing, with the result that the use of automation would no longer have justified the utilization costs. The applicapility of the information obtained in detecting variations in loading was reduced by great variations occurring in both the water quality and quantity caused by a upstream water regulation and the varying water requirement of a downstream hydroelectric plant. Utilization of the results would have necessitated detailed investigation of these factors and the construction of a complex flow model. The aims of the development work were therefore not achieved as such.

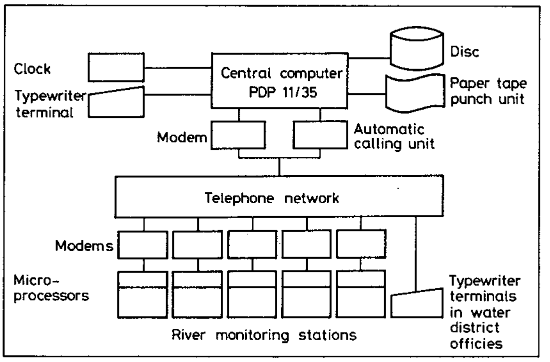

Fig. 1. Automatic water quality monitoring system of the rivers Kymijoki and Kokemäenjoki.

2.2 The monitoring system of the river Kymijoki

This system, of which the central unit is the PDP 11/35 computer and its peripheral devises at the NBW, has previously been described in detail by Kohonen and Lee-Frampton (1979). Data transfer, from the fixed program memory-equipped microprocessors located in the river stations to the computer, is effected using an automatic public telephone transmission line activated twice daily by the computer (Fig. 1). Every morning the central unit prints a daily report, containing station-specific data on warning levels and faulty operation, half-hourly averages and extreme measurement values. The Kymi Water District Office also has access to the computer for reports at its own terminal.

The parameters measured at the river stations are temperature, pH, conductivity, dissolved oxygen and turbidity. At three of the stations chloride is also measured. The electrodes receive an automatic ultrasonic cleaning every hour and the pH, conductivity, oxygen and chloride measurements are recalibrated daily, also automatically. All the stations are equipped with a 24-bottle SAM-100 alarm sampler. Water for measurements and sampler is taken with a submersible pump with a capacity of 60—100 $l\ min^{-1}$.

In 1979 a new agreement was made to replace the 1974 agreement on the development of the automatic monitoring system for the river Kokemäenjoki. According to the new agreement, two of the five river stations originally positioned in the river Kymijoki were transferred to the river Kokemäenjoki. Thus the Tampere Water District Office could also obtain reports on its own terminal.

2.3 The mobile stations

In 1974 the first, and in 1976 the second mobile

AWMS was delivered. The stations, housed in caravan-type trailers, were built by Philips and measure the following parameters continuously: temperature, pH, conductivity, turbidity, dissolved oxygen, chloride and when necessary the oxidation-reduction potential. A submersed pump continuously delivers 60–100 l min^{-1} of sample water to the electrodes, which are located in a continuous-flow measuring chamber. The stations are equipped to carry out ultrasonic cleaning of the electrodes every hour and calibration of the pH, conductivity, oxygen, chloride and redox electrodes once daily. The stations also have an alarm sampling system.

The analog signals from the electrodes are registered in both stations on two-channel recorders. In the first station the daily and half-hourly averages calculated by the datalogger are registered on the printer and on punched tape. In the second station the averages are calculated by a microprocessor and recorded on a strip-printer and a C-casette. Subsequent further data processing takes place using the central computer of the automatic monitoring system (Fig. 2).

At the end of 1980 a new AWMS built by Oy Labko Ab was delivered. This station does not require water to be pumped inside. Instead, a probe measuring five parameters is immersed in the watercourse, from which electronic signals are transferred to a shore-based microprocessor and thence to a recording unit.

3. FUNCTIONING OF THE AUTOMATIC MEASURING STATIONS

During the first operation years of the monitoring system of the rivers Kymijoki and Kokemäenjoki the main disturbances occurred in water supply and in the functioning of the microprocessors, while more recently faults in the operation of the central computer have caused substantial loss of data. Due to lack of resources for service and maintenance 1–7 days were lost before service aid could be obtained from Helsinki.

Overall averages for the years 1977–1981 of the annual operation averages calculated for the six parameters measured by the five stations of the monitoring system were best for

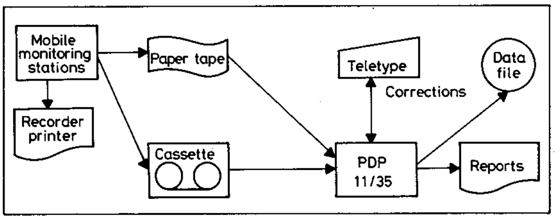

Fig. 2. Information system of mobile water quality monitoring stations.

Table 1. Parameter-specific[1)] operational efficiencies (%) for the five monitoring stations of the rivers Kokemäki and Kymijoki system.

	1977	1978	1979	1980	1981
Temperature	98	100	99	96	94
pH	94	84	73	72	76
Conductivity	96	79	63	78	85
Dissolved oxygen	81	78	32	75	62
Turbidity	97	95	96	96	91
Chloride	76	83	49	51	48

1) Parameter-specific operational efficiency = $100 \dfrac{\text{durations of measurements}}{\text{operation time-downtime}}$

the temperature and turbidity measurements and poorest for chloride (Table 1).

The functioning of the stations and parameters was influenced considerably by the time of year and by local conditions. In winter, pumps and tubes were broken by ice, while in summer pumps, tubes and measuring chambers were clogged in the heavily loaded waters. Disturbances in the supply of electricity caused considerable difficulties, particularly in winter.

The data availabilities concerning the mobile stations is also presented (Table 2). Parameter-specific operational efficiencies varied considerably with the location of the measuring station. For the first mobile station the averages of the 6–year location-specific operations were best for pH and oxygen (98 % and 97 %) and poorest for conductivity (78 %). For the second station the best mean operational efficiency was for temperature (99 %) and the poorest for chloride (82 %).

At the end of 1980 the NBW took delivery of the third mobile AWMS built by Oy Labko Ab, which during the specified one-month trial period achieved a operational efficiency of 99.8 % per parameter, the required efficiency

Table 2. Total utilization rates[1] for the mobile monitoring stations, parameter-specific operational efficiencies[2] and reasons for breakdowns with proportions of operation time.

Location Operation period	Utilization rate		Parameter-specific operational efficiency (%)						Reasons for breakdown, percentage of operation time			
	Days	%	Temperature	pH	DO	Conductivity	Turbidity	Chloride	Service	Pump	Electricity	Others
MOBILE STATION I												
Karhula, Kymijoki 9.9.–11.12.75	63	50	100	100	100	58	73	82	3.2	35.0	11.0	Calibration 0.5
Koria, Kymijoki 18.12.75–13.5.76	147	45	100	99	99	30	64	71	0.5		8.2	Freezing 44.4
Vaajakoski, Haapakoski 14.5.76–4.3.77	327	88	68	98	68	44	97	47	2.0	9.5	0.1	Microprocessor 0.2
Ruukki, Siikajoki 5.3.–3.8.77	151	81	100	100	100	100	100	98	1.1	17.9	0.2	
Simpele, Kokkolanjoki 5.8.–27.12.77	144	97	100	100	100	100	99	97	0.7		0.4	Freezing 2.2
Nokia, Kokemäenjoki 17.3.–21.9.78	184	98	84	100	100	97	86	95	1.5		0.1	
Annila, Vanajavesi 8.12.78–3.1.79	25	29	60	100	100	100	100	100	2.1		48.7	Microprocessor 20
Rauduskylä, Kalajoki 2.2.–26.4.79	81	98	84	100	100	46	66	100	1.2		0.8	
Tervakoski, Tervajoki 6.6.–17.9.79	120	98	100	95	99	83	97	76	1.8			
Orimattila, Porvoonjoki 23.5.–9.10.80	138	98	100	88	100	100	100	94	0.5	0.7	0.7	
Vantaa, Pitkäkoski 1.6.–30.9.81	120	90	100	100	96	97	95	95	0.6	3.1	5.9	
MOBILE STATION II												
Jämsänkoski, Jämsänjoki 13.8.–8.11.76	87	90	100	80	72	55	79	46	4.0	6.0		
Kuusamo, Oulankajoki 9.11.76–9.3.77	122	96	100	89	72	100	84	82	1.5	0.2	0.5	Microprocessor 2.0
Lepaa, Vanajavesi 11.5.–8.9.77	120	96	90	77	89	99	100	77	1.9	2.3		
Lempäälä, Vanajavesi 13.10.–19.1.78	98	88	100	100	100	100	100	100	0.6		11.5	
Ala-Okeroinen, Porvoonjoki 6.4.–6.9.78	152	96	100	100	100	100	91	91	1.7	1.9	0.1	
Konhonvuolle, Vanajavesi 19.9.78–3.1.79	106	82	100	100	89	94	78	94	1.8	6.7		Valve 9.1
Harviala, Hiidenjoki 22.8.–22.10.79	59	94	100	93	67	100	92	98	3.2			Microprocessor 2.8
Jyväskylä, Tourujoki 21.5.–28.8.80	98	99	100	100	81	100	100	89	0.4	0.6	0.1	
Renko, Renkajoki 29.8.–5.11.80	67	97	98	91	98	80	86	60	1.4	1.4	0.3	
Vantaa, Keravanjoki 1.6.–30.9.81	120	91	100	94	92	94	98	80	0.8		0.1	
MOBILE STATION III												
Jokioinen, Loimijoki 27.4.–29.6.81	62	69	100	100	87	100	100		0.2			Microprocessor 30.8
Helsinki, Vantaanjoki 30.6.–10.9.81	71	99,5	100	100	100	100	100		0.3		0.2	
Lohja, Risubackajoki 22.9.–20.10.81	36	100	100	100	100	100	100					
Kokkola, Kemira Oy 30.10.81–13.1.82	74	88	100	100	88	100	91		1.0		7.4	Microprocessor 3.7

1) Total utilization rate = 100 $\dfrac{\text{operation time} - \text{downtime}}{\text{operation time}}$

2) Parameter-specific operational efficiency = 100 $\dfrac{\text{durations of measurements}}{\text{operation time-downtime}}$

being 90 %. Repeatability tests for each parameter also fulfilled the set requirements: temperature $\pm 0.5^{o}C$, pH ± 0.2 units, conductivity ± 5 %, dissolved oxygen ± 3 % and turbidity ± 10 %. In order to check the reproducibility of analysis a comparison of the results of the automatic station with laboratory analyses was carried out. The Student's t-test did not reveal any differences between the two sets of results at the 5 % risk level. The data availabity is also presented for the Labko station (Table 2, mobile station III).

4. RESULTS OBTAINED USING THE STATIONS

4.1 Monitoring system

A considerable temporary change took place in the loading of the upper reaches of the river Kymijoki at the end of May 1977, when the sulphite cellulose mill at Kuusankoski ceased operation. The results registered by the Keltti and Salonsaari water monitoring stations revealed major fluctuations in water quality in the river Kymijoki over the period 21.5.–1.6. This was

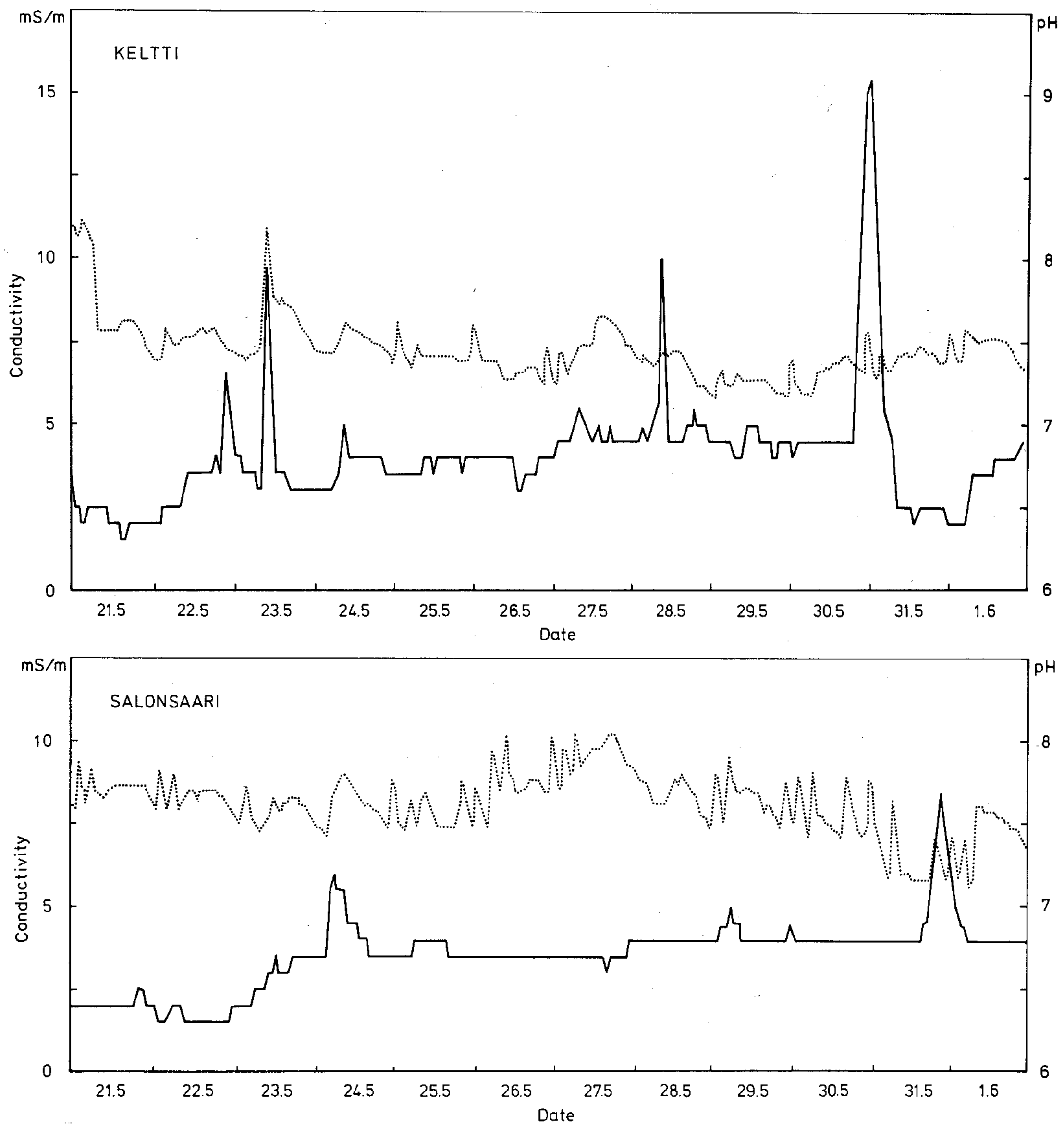

Fig. 3. Variations in pH (–) and conductivity (....) at the Keltti and Salonsaari monitoring stations in the river Kymijoki during the period 21.5.–1.6.1977.

particularly evident in the measurement of pH (Fig. 3). The greatest variation at the Keltti station was on 30.–31.5. almost three pH units, the highest reading being 9.1. The average pH value for the water of this river over the period 1974– 1976 was 6.48, while the extreme values previously measured by manual sampling were 7.70 and 6.05. Thus during the period covered by Fig. 3, the earlier maximum value of pH was exceeded on three occasions. The changes recorded at Keltti were observed about twenty hours later at Salonsaari, the greatest variation being of the order of one pH unit.

Strong variation was also observed in values of conductivity during the same period. The greatest variation was in Keltti about 4 mS m^{-1} and in Salosaari about 2 mS m^{-1} the maximum conductivities being 10.9 and 10.2 mS m^{-1}, respectively. The 1974–1976 average for the river Kymijoki was 6.98 mS m^{-1}, with extremes of 9.1 and 6.2 mS m^{-1}. On some occasions rapid changes were observed simultaneously on both pH and conductivity readings, whereas sometimes only one or other of the parameters exhibited major variation.

Reductions of 3–5 % were observed in oxygen saturation values in Keltti during the pH and conductivity peaks.

The reason for the observed changes in water quality was in all probability variation in loading upstream of the measuring stations. Definitive identification would, however, have required more specific and detailed information on operations and discharges than were made available to the water authorities by the polluting agency.

On Friday evening 5.6.1981 about 10 p.m. the uppermost station (Keltti) of the river Kymijoki network registrated rapid increase in turbidity, conductivity and pH value (Fig. 4). Turbidity values exceeded the upper limit (100 FTU) of measuring range over an hour's time. On the basis of once per minute measurements, which were presented as half-hourly means, the highest momentary pH value was 9.2. The change in water quality could be found two days later in the results of the lower station (Hirvivuolle). Accidental spill from big pulp and paper factory caused the changes with the result that tons of fish died.

In the utilization of the data produced by the river Kymijoki system it was observed that, particularly for oxygen and conductivity, considerable daily and weekly variation occurred. In the case of dissolved oxygen annual variation was also observed. Thus the loading to the river would also appear to be rhythmic in nature.

The two stations in the Nokianvirta reach of the river Kokemäenjoki, transferred from the river Kymijoki in 1980, were situated about four kilometres before (Sattula) and four kilometres after (Melo) the Nokia pulp and paper factory. The water requirements of the hydroelectric plant at the lower measuring station (Melo) have a considerable influence on residence time and, therefore also on water quality. During prolonged closures waste waters may even move for short distances upstream.

In July 1980 extensive fish death occurred in Nokianvirta when the oxygen concentration of the water reached zero and the pH 5.0. The reduction in oxygen level was caused by high water temperature, an unusually long bypass at the Melo hydroelectric plant and a high effluent loading.

Daily averages of oxygen concentration still varied between 16 and 37 % of the saturation value at the lower station at the end of September. The oxygen consumption caused by effluent loading was apparently still great during this period, as the corresponding oxygen concentrations at the upstream measuring station were 69–78 % of the saturation value. Because of heavy rains at the beginning of October it became necessary to increase the flow, with the result that the oxygen concentration values at the Melo station improved to 50 % of saturation. Of this improvement, about 10 % was a direct result of the high oxygen content of rain water and was also discernable at the Sattula station (Fig. 5).

4.2 The mobile stations

The results of monitoring in the river Porvoonjoki in summer 1978 indicated that the condition of the river was poor, especially with regard to oxygen concentration (Fig. 6). In addition to the generally low oxygen level, a clear weekly fluctuation was also observed, with minimum values between Thursdays and Saturdays and maximums on Mondays. Conductivity readings revealed a typical reduction in electrolyte concentration caused by the spring flood. Conductivity decreased regularly from Monday to Tuesday (Fig. 6). Both the generally poor water

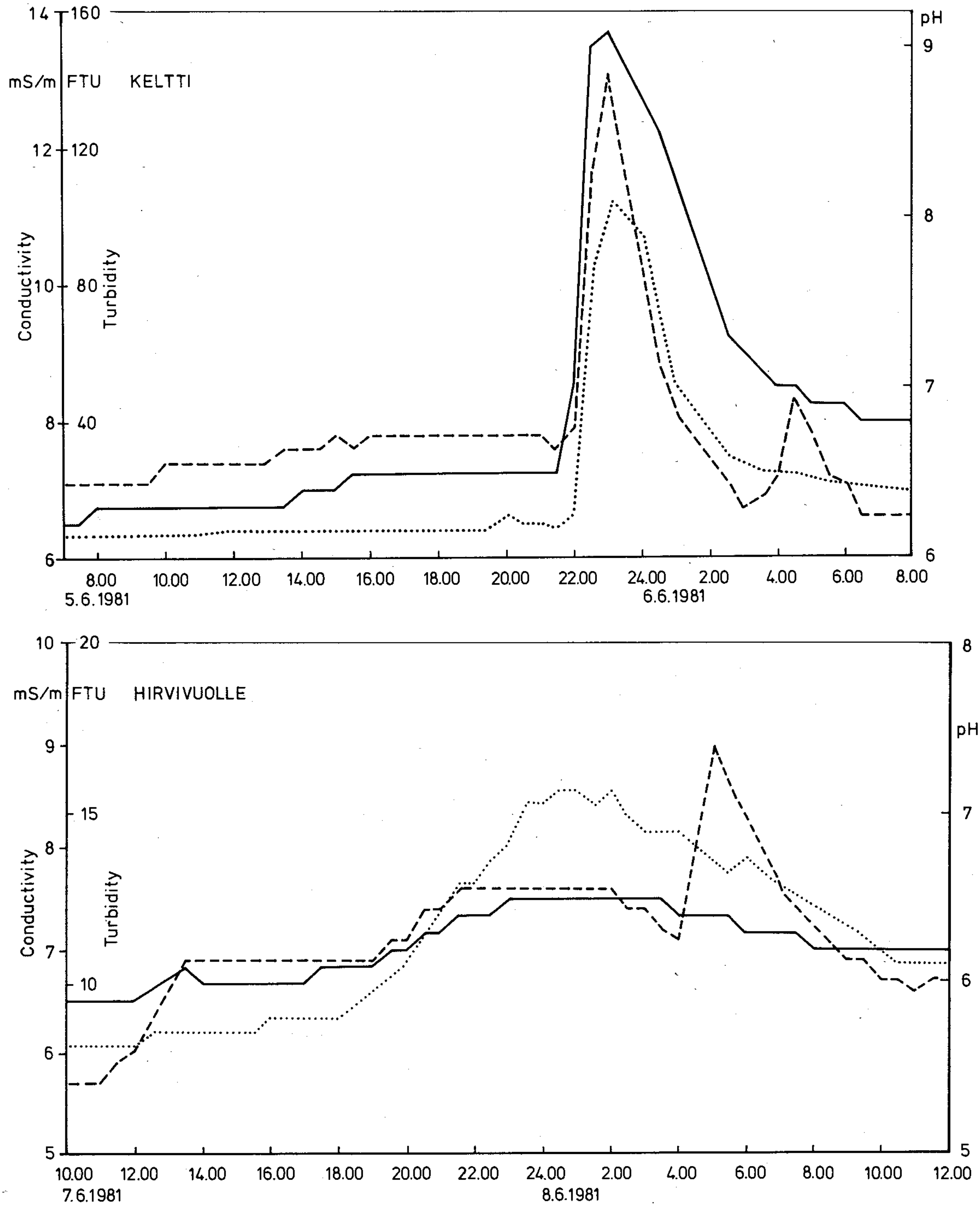

Fig. 4. Variations in pH (–), conductivity (- - -) and turbidity (....) at the Keltti and Hirvivuolle monitoring stations in the river Kymijoki during the period 5.–8.6.1981.

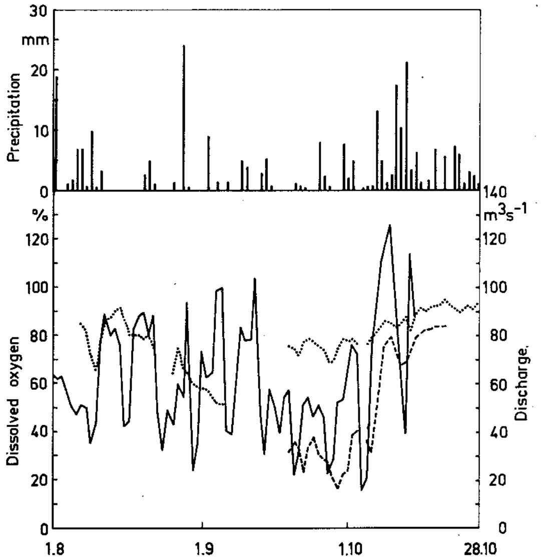

Fig. 5. Daily means of DO at the Sattula (....) and Melo (- - -) monitoring stations, discharge at the Melo hydroelectric plant (—) and daily precipitations in the river Kokemäenjoki during the period 1.8.–28.10.1980.

quality of the river and the quality variations observed appeared to be clearly connected with operations at the waste water treatment plant situated upstream of the measurement station.

Monitoring in the river Tervajoki about one kilometre downstream of a pulp and paper mill indicated that the river water was strongly polluted by the mill. The measured parameters - pH, oxygen, conductivity and turbidity- showed values varying from one extreme to the other during the course of a single day and indicated potentially catastrophic situations on several occasions (Fig. 7).

5. UTILIZATION OF RESULTS

5.1 Aims and problems of monitoring

The aim of the monitoring of water quality is to generate information for the requirements of water utilization and protection. Monitoring density, i.e. the amount of information produced, is a major consideration in the planning of monitoring systems. In the case of both automatically and manually obtained results, the user must be able to specify his needs and the required accuracy and reliability of primary data. It is no advantage to produce reports and statistical treatments even from automatic monitoring if no benefit is to be obtained from the information.

One of greatest limitations at the present time is the lack of sufficient automatically measurable parameters. However, in the case of parameters which can already be measured, it is possible to create a station-specific alarm system for the exceeding of threshold values, with an output to the user. The water quality upstream of any given source of pollution also sets a limit on the use of automatic monitoring. If the upstream water is already heavily polluted some discharges may well remain undetected with the present measuring parameters and accuracies. Although the reliability of automatic analyses is still not sufficient in all conditions it is possbile to use the results for alarm purposes by comparison of relative values.

In addition to satisfying the immediate need for information (confirmed by alarm sampling), automatic monitoring also generates considerable amounts of data concerning water quality in general. This information should be utilized as efficiently as possible. One common problem in water quality monitoring is the lack of sufficient data concerning both quality and quantity of water. In practice this implies the distribution of sampling frequencies according to the known necessity for information. This raises the question of optimal sampling frequency. The required frequency depends on the use to which the water quality data are to be applied. The commonest forms of data utilization are:

- determination of amounts of materials carried with the water flow
- estimation of regular variation in water quality at the sampling station
- detection of irregular discharges.

When it is required to determine the total loading carried by a river, observations should be made with reference to the hydrological year rather than to the calendar year. Each observation site and loading parameter must be assigned its own minimum observation program. The frequency of observations should be decided on the basis of quantities of materials rather than concentrations. The lack of sufficient automatically measurable water quality parameters

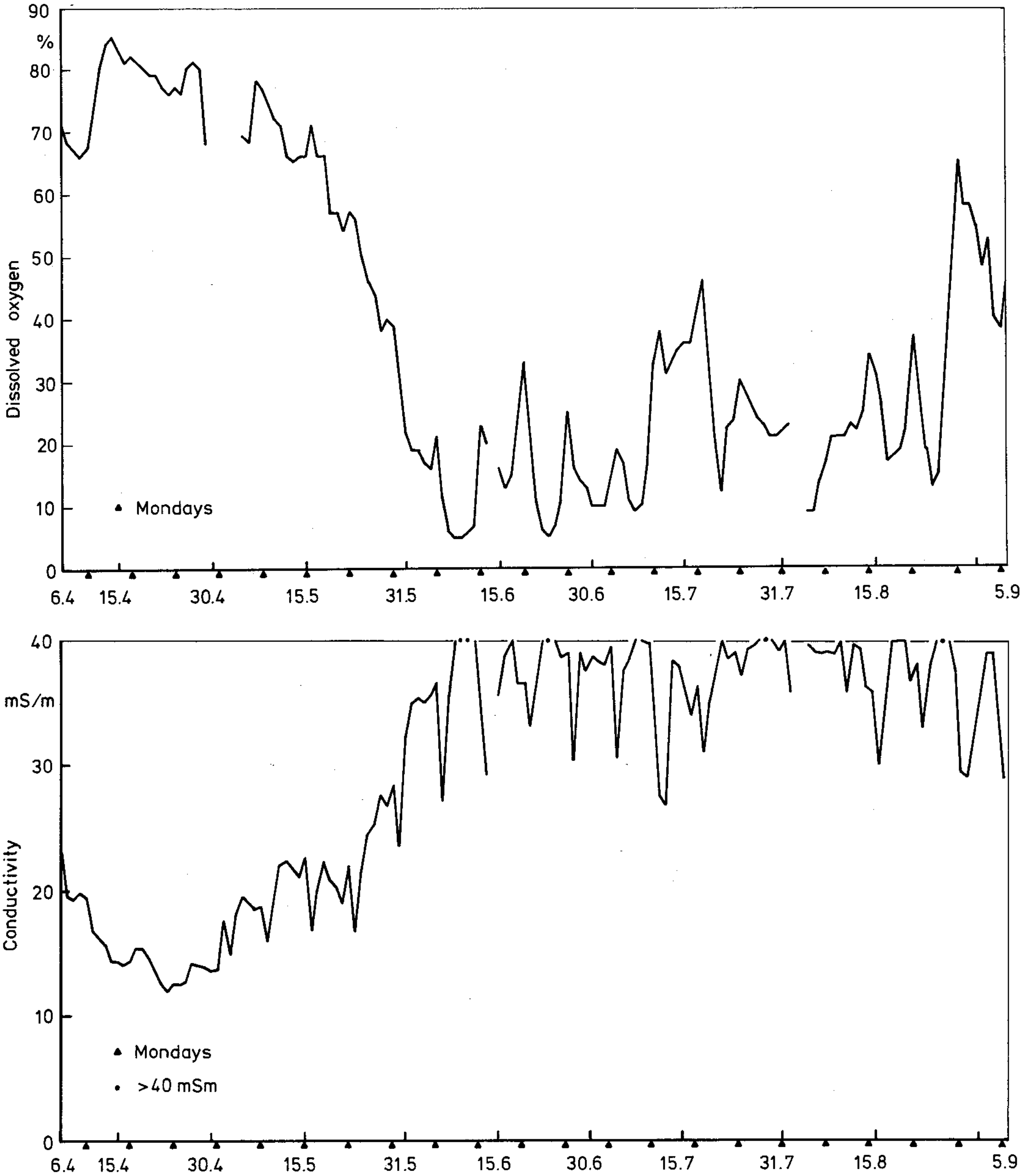

Fig. 6. Daily means of DO and conductivity, calculated from half-hourly means measured by AWMS in the river Porvoonjoki in 1978.

has for the present limited, if not actually eliminated, the use of automation in the investigation of amounts of loading.

The observation of regular variation requires a regular sampling program. Sampling frequency depends on the variation period which it is desired to disclose. The sampling interval should be at least half of the smallest period of regular variation to be revealed. In practice, automation enables almost limitless reduction of the sampling interval. A suitable monitoring frequency can then be selected for any given situation by appropriate utilization of data handling equipment.

The detection of irregular discharges requires continuous measurement. It is not, however,

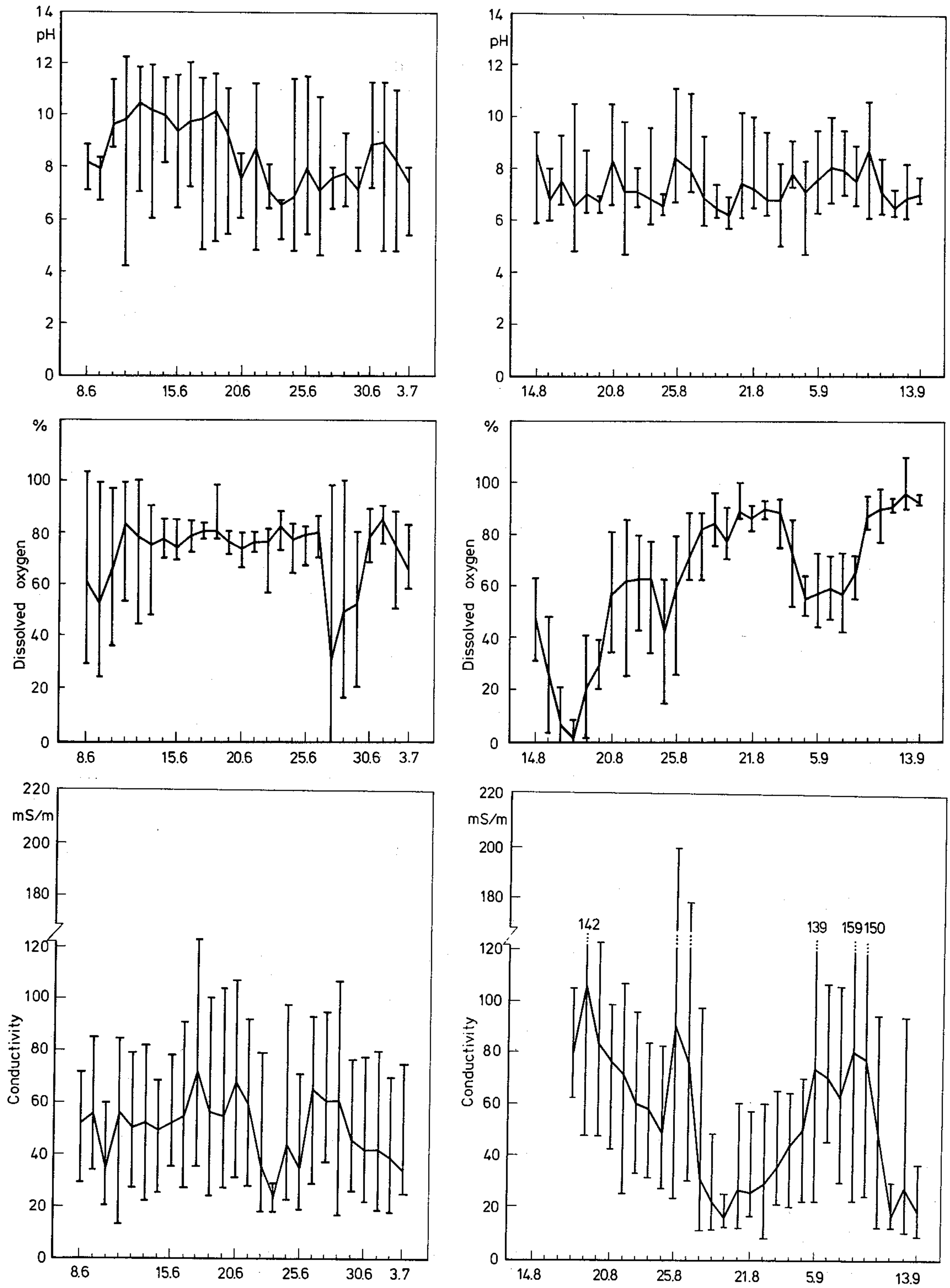

Fig. 7. Daily means, minimum and maximum half-hourly means of pH, DO and conductivity measured by AWMS in the river Tervajoki in 1979.

necessary to measure all the parameters if suitable continuously measurable indicators and an automatic alarm sampler are available. Thus automation can be successfully applied to the detection of irregular discharges.

5.2 Determination of optimal sampling frequencies

Specification of the optimal sampling frequency at a particular site should take into account the following factors:

- different data requirements of different activities
- special circumstances at the sampling site
- available resources

Consideration of these factors very often leads to a conflict between the amount of data required and the extent of resources available. Sampling frequency should be adjusted so that the required information can be obtained with the minimum of sampling. This aim is made more difficult by the fact that the amount of information does not increase linearly with increase in the number of samples.

In the case of manual sampling it is often difficult to obtain sufficient information, whereas with automatic stations the reverse is true. Automatic stations continuously generate measurement results, which may disclose irregular discharges, but the storage and handling of all the generated data for future use in research and planning is not realistic. It should be attempted to calculate the largest permissible sampling interval for manual sampling and the smallest realistic data storage interval for automatic measurements.

Using the data generated by mobile automatic stations, it was attempted to determine the monitoring frequency necessary to obtain a given confidence level of the mean. The confidence interval, L, of the mean of n results, defines the range around the mean in which the true mean lies at a given confidence level. The confidence level is the percentage of the occasions on which the true mean will be within the confidence interval, L.

The required number of samples, n, for the determination of the mean in a normally distributed data with a confidence interval, L, is given by

$$n = (2k\sigma/L)^2 \tag{1}$$

where

σ = estimated population standard deviation, calculated from sample values
n = number of samples
k = coefficient, the value of which depends on the chosen confidence level (Table 3)
L = confidence interval

Table 3. Values of k at some confidence levels, L.

Confidence level %	99	98	95	90	80	68,3	50
k	2.58	2.33	1.96	1.64	1.28	1.00	0.67

Although the determination of sampling frequency by equation (1) or its derivatives is based on normally distributed data, the equation has also been used when only the estimate (s) of the standard deviation (σ) is known (Deininger 1971, Loftis 1979, Montgomery and Hart 1974, Sanders 1974, Sanders and Adrian 1978, WHO 1977, ISO 1980, Ward et al. 1979, Simpson 1980a, b).

The half-hourly means from the rivers Porvoonjoki, Tervajoki and Hiidenjoki were used to calculate the number of samples for determination of the means of measured parameters at the 95 % confidence level within the 20 % confidence interval (Table 4).

In the river Porvoonjoki, in which regular water quality variation occurs, oxygen levels and turbidity should be monitored daily. In the river Tervajoki variation was irregular and turbidity should be monitored three times and conductivity twice per day (Kohonen 1981). In the river Hiidenjoki, in which only minor water quality variation occurred, it would be sufficient to monitor conductivity every fourth day and turbidity every sixth day.

Table 4. Required sampling frequencies in the rivers Porvoonjoki, Tervajoki and Hiidenjoki for determination of the means at the 95 % confidence level within the 20 % confidence intervals.

	Samples per time unit		
Parameter	Porvoonjoki	Tervajoki	Hiidenjoki
pH	very rarely	1/4 days	1/2 months
conductivity	1/4 days	2/1 day	1/2 days
DO saturation %	1/1 day	1/1 day	1/12 days
turbidity	1/1 day	3/1 day	1/3 days

6. DEVELOPMENT POTENTIAL

The widespread use of automatic monitoring of water quality is limited by the lack of suitable sensors. For this reason automatic monitoring cannot at present replace manually conducted obligatory monitoring, in which it should be possible to measure the quality and quantity of permitted waste water, as well as effects on receiving waters. Monitoring in watercourses is in fact the monitoring of changes after their occurrence. Exceptional changes, for example after irregular discharges, can only be prevented by monitoring their formation during different process stages. The greatest preventive advantage of the use of automation would be obtained by using automation in process monitoring and control. Waste waters appearing as a result of process disturbances could be led to storage tanks, thus avoiding poisoning of the biological treatment process. After investigation of the quality parameters of the stored water, the water could be led in small batches to the treatment plant. Thus the functioning of the plant would be undisturbed and the quality of the water discharged to the watercourse would be more constant. The use of automatic measuring equipment just after the treatment plant would yield continuous data concerning both loading and the efficiency of the treatment plant. The data could be utilized immediately by the polluting unit in the regulation of the treatment plant. Both the water protection authorities and the polluter would receive the same data concerning loading to the receiving water and the effects of the loading on water quality. Technically, the frequency of data reporting could be chosen at will.

Another limiting factor for automatic monitoring is the fact that, depending on the quality of the water to be measured, the reliability of the results is not always satisfactory (Kohonen 1978b, National Board of Waters 1978, Kohonen and Lee-Frampton 1979). Reliability can be improved by preventive maintenance and in certain situations by automatic calibration and cleaning. Some of the parameters measured in obligatory monitoring are such that their automation necessitates frequent manual servicing. At least in the case of process measurements and measurements in final discharges, the required maintenance should be the responsibility of the polluter. In waste water monitoring the reliability and sufficiency of data must be evaluated from flow-dependent samples. If a manual method is insufficient it should be possible, with the aid of efficient maintenance, to obtain more precise data on quality changes for certain parameters using automatic methods. In some cases measurements of indicators of loading should be sufficient.

The third problem associated with automatic monitoring and high data-production frequencies is the loss of data as a result of technical faults. This problem can be partially solved by equipping the stations with several types of data storage units, for example punch tape and printer. Using such apparatus the data is always available as long as the actual measurement is operational.

Intensive research and development work is being carried out in many countries in order to adapt new parameters to automatic measurement. It is most likely that the automatic measurement of organic loading, some nitrogen and phosphorus compounds, and specific ions will become available in the near future.

On the basis of the experience gained in this investigation it is apparent that an automatic station equipped with a submersible measurement probe is particularly advantageous for year-round monitoring and for regions with difficult water availability. The use of such automatic stations aids waste water measurement because there are no pumps and tubes to become clogged and because corrosive gases do not enter the station, where they would cause damage to electronic equipment. The possibility of using ultrasonic cleaners, shown to be highly efficient in this context, is another advantage of this type of station.

7. SUMMARY

Automatic water quality monitoring may produce new and useful data. Manual sampling and analysis imposes a practical limit on the data interval. The utilization costs of automatic monitoring are not, however, dependent on sampling frequency. The limitations of automatic monitoring are the number of parameters that for the present can be measured and, depending on use conditions, the necessity for servicing.

Automatic monitoring is essential if water quality variations and water utilization necessi-

tate frequent and continuous availability of data.

Monitoring with automatic stations has in several cases revealed previously undetected water quality variation. The 5–6 parameters measured by the stations have been sufficient to demonstrate general changes in water quality. The results obtained have been utilized e.g. in inspections.

The automation of monitoring of the quantity of waste waters is now both technically and economically feasible. Additional measurements of water quality which will become available in the coming years will increase the possibilities of automation of load monitoring.

The statistical processing of the data produced by automatic stations makes possible the calculations of the optimal sampling frequencies for different confidences of results.

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LOPPUTIIVISTELMÄ

Tutkimuksen tarkoituksena on esitellä vesihallituksen käyttämät automaattiset veden laadun tarkkailujärjestelmät ja -asemat sekä asemien toimivuudet ja niiden tuottamia tuloksia. Myös tulosten hyödyntämisen eri mahdollisuuksia ja automaattisen veden laadun tarkkailun kehitysnäkymiä käsitellään.

Vesihallituksen käytössä on ollut 11 automaattista veden laadun tarkkailuasemaa, joista 5 muodostaa tietokoneen ohjaaman järjestelmän Kymijoella ja Kokemäenjoella ja loput ovat helposti kohteesta toiseen siirrettäviä asemia. Mitattavat muuttujat ovat lämpötila, pH-luku, sähkönjohtavuus, liuennut happi ja sameus sekä viidellä asemalla kloridi.

Asemien toimintaa ovat eniten häirinneet vaikeudet veden saannissa sekä mikroprosessorien ja keskustietokoneen toiminnoissa. Muuttujakohtaiset toiminta-asteet ovat vaihdelleet havaintopaikasta riippuen 30–100 prosenttiin mittausajasta (taulukko 1 ja 2).

Automaattisella tarkkailulla on monissa kohteissa havaittu ennen tiedostamatonta veden laadun vaihtelua (kuvat 3–7). Käytetyistä 5–6 muuttujasta on aina jokin ilmaissut veden laadun muutoksen. Saatuja tuloksia on voitu hyödyntää mm. katselmuksissa. Asemien tuottamaa tiheää havaintoaineistoa on hyödynnetty tilastollisia menetelmiä apuna käyttäen määritettäessä tarvittavaa havaintotiheyttä tietyn luotettavuuden saamiseksi lasketuille keskiarvoille (taulukko 4).

Automaattinen vesistötarkkailu voi tuottaa oleellisesti uutta ja käyttökelpoista tietoa. Manuaalista näytteenottoa ja analysointia ei voida eri syistä tihentää rajattomasti. Automaattisen tarkkailun käyttökulut eivät sitävastoin ole riippuvaisia havaintotiheydestä. Sen rajoituksina ovat toistaiseksi mitattavien muuttujien määrä ja mittausoloista riippuva huollon tarve.

Automaattiasemien tuottamista tiedoista laskettujen tunnuslukujen luotettavuuksien edellyttämät optimaaliset näytteenottotiheydet voidaan määrittää aineiston tilastollisen käsittelyn avulla.

Automaattista tarkkailua voidaan pitää välttämättömänä, jos veden laadun vaihtelut ja sen käyttömuodot edellyttävät tiheää tai jatkuvaa tiedon saantia.

Jätevesien määrän tarkkailu on nykyisin mahdollista automatisoida sekä tekniset että taloudelliset näkökohdat huomioon ottaen. Lähivuosina rutiinikäyttöön tulevat veden laadun lisämittaukset antavat mahdollisuuksia automatisoida myös kuormitustarkkailu.

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